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OF ELECTRIC SHOCK IN
LEARNING A STYLUS MAZE

A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY
1934

By
MARION ESTEL BUNCH

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CERTAIN EFFECTS OF ELECTRIC SHOCK IN LEARNING A STYLUS MAZE

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INTRODUCTION

In almost all studies of the influence of electric shocks for errors upon learning, the shock has been administered as punishment for all, or certain, errors throughout the entire learning process. This procedure characterizes the experiments with human subjects by Barlow (1), Bunch (2), Bunch and McTeer (3), Crafts and Gilbert (5), Dodson (7), Jensen (9), Lorge (11, 12), McTeer (14, 15), Rexroad (18), Tolman, Hall and Bretnall (19), and Vaughn and Diserens (21), and with animal subjects the studies by Cole (4), Hogue and Stocking (8), Dodson (6), Kuo (10), Muenzinger (16), Ni (17), and Yerkes and Dodson (22). Although these studies differ from each other in a number of important respects such, e.g., as the kind of problem learned, the intensity of shock used, methods of measuring learning, etc., the results presented in most of them are in agreement in indicating that there is, as a result of electric shocks, (a) a decrease in errors (1, 2, 3, 4, 5, 6, 7, 8, 9, 14, 15, 16, 17, 18, 21, 22), (b) a decrease in the number of trials when the latter was used as a measure of learning (2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 16, 17), and (c) an increased attitude of caution on the part of the subjects which is usually reflected in an increase in time per trial (1, 2, 14, 15, 18). In addition, a decrease in the total time required for learning has been found in some experiments in which the number of trials was a variable in learning and a fairly long series of trials was required to reach the level of efficiency desired. Also, several studies sug-

¹ I wish to express my gratitude and to acknowledge my indebtedness to Professor Harvey A. Carr for many valuable suggestions and criticisms concerning this investigation.

gest that for a given problem the efficiency of learning varies with the intensity of the electric shock used, that the optimal intensity of shock for efficient learning varies with the difficulty of the problem, and that the optimal intensity for simple problems probably lies closer to the maximum intensity end of the scale than is the case with difficult problems. That electric shocks for errors may yield detrimental rather than beneficial results under certain conditions is indicated by the studies of Tolman, Hall and Bretnall, and Lorge.

An exception to the general procedure of administering electric shock as punishment for errors mentioned above is involved in the experiment on maze learning in white rats reported by Valentine (20). In this experiment punishment for errors was introduced in one case at the 50 per cent point in the learning process—the point at which only one-half as many blind alleys were entered in a trial as was expected in the long run on the basis of chance—and continued until the criterion of mastery was met, and in another case at the 75 per cent point and continued thereafter. These two conditions of learning were employed in addition to administering punishment for errors throughout learning and to the normal non-punishment condition. Each of the three conditions of administering punishment was superior in terms of errors to learning without punishment. Punishment for errors throughout learning was the most efficient condition, and punishment introduced at the 75 per cent point and continued thereafter decreased total errors slightly more than when introduced at the 50 per cent point.

The present investigation is concerned with certain other problems in regard to the influence of electric shocks for errors upon learning. In studying these problems the efficiency of learning was measured under a variety of conditions, and the general conditions which were common to all parts of the experiment will be mentioned first.

Human subjects were used in the study and the problem to be learned was a stylus maze. The maze, described in detail in an earlier report (2), was of such a character that the subject could be given an electric shock when the metal stylus came in contact

with the end of a blind alley. The shock was felt in the fingers grasping the stylus. No shock was given for retracing in the true pathway or for partial entrance into a cul-de-sac, although such movements were of course counted as errors. A shock of 27 volts A.C. was used, and the intensity was kept constant for all subjects receiving punishment in the experiment. The criterion of mastery was 4 errorless records in 5 trials. The subjects who took part in the experiment were students from classes in Introductory Psychology and they were divided into groups on the basis of certain particular conditions under which learning took place (summarized in table 1), as will be described later. There were 14 groups in all, and no group contained fewer than 26 subjects.

PROBLEM 1. IS THE EFFECT OF ELECTRIC SHOCKS ENTIRELY A
FUNCTION OF THE INFORMATIVE VALUE OF ADMIN-
ISTERING THE SHOCKS FOR ERRORS?

The influence of electric shocks upon learning is obtained by a comparison of the records of group S, which received a shock at the end of each blind alley throughout learning, with those of group N which learned the problem under normal conditions. The learning scores are shown in table 2, and comparative data are presented in table 3. Group N, to reach the criterion of mastery, took 45.21 trials, 1463.39 seconds, and made 449.19 errors. The corresponding figures for group S are: 18.31 trials, 1030.15 seconds, and 216.55 errors. The maze was thus mastered under the S condition in 59.5 per cent fewer trials, 29.6 per cent less time, and with 51.7 per cent fewer errors than under normal conditions. These differences, indicating the superiority in learning the maze when electric shocks are used, are large, consistent, and have, statistically, a high degree of reliability as indicated by the ratio of each difference to its sigma (table 3).

Presumably the introduction during learning of any variable which facilitates differentiation of correct from incorrect acts is likely to be followed by increased learning efficiency. Compared with ordinary maze-learning conditions, an electric shock at the end of each blind alley in the maze represents a rather pronounced

additional cue which characterizes blind alley segments as distinct from true pathway segments. An attempt was made to determine the informative value in learning the maze of a marked additional cue which serves to define blind alley segments more sharply and clearly than occurs under ordinary conditions, apart

TABLE 1
Program of the conditions of learning for each group

GROUP	NUMBER OF SUBJECTS	CONDITIONS OF LEARNING		
N	100	Normal maze-learning conditions (control group)		
Sa	40	Shock for errors throughout learning but no reference to such in instructions		
S	54	Shock for errors throughout learning and informed of this fact in instructions		
VC	34	Verbal cue instead of shock at end of each blind alley		
		<i>Shock limited to initial trials</i>		
		NUMBER OF INITIAL TRIALS DURING WHICH S WAS GIVEN	MAZE-LEARNING CONDITIONS	
S2	34	2	Normal	
S4	26	4	Normal	
S8	30	8	Normal	
S12	28	12	Normal	
		<i>Shock introduced during learning process</i>		
		NUMBER OF TRIALS PRIOR TO INTRODUCTION OF S	NUMBER OF TRIALS WITH S	MAZE-LEARNING CONDITIONS
S3-4	26	2	2	Normal
S3-6	28	2	4	Normal
S3-10	30	2	8	Normal
S3-14	30	2	12	Normal
S5-6	30	4	2	Normal
S5-8	30	4	4	Normal
S5-12	33	4	8	Normal

from the other supposed aspects resulting from administering electric shocks. The individuals in group VC received a verbal cue at the end of each blind alley during learning, and they were informed in their instructions of this feature of the learning situation. The experimenter said the word "blind" when the subject

moved the stylus to those places in the maze at which shock was administered in group S. A comparison of the efficiency manifested by group VC in the mastery of the maze with that of group N, which learned the maze under normal conditions, will indicate

TABLE 2
Learning data

GROUP	TRIALS		TIME		ERRORS	
	Average	σ average	Average	σ average	Average	σ average
N	45.21	4.29	1463.39	116.94	449.19	48.04
Sa	20.60	1.58	1065.29	113.06	254.30	35.06
S	18.31	2.21	1030.15	70.77	216.55	21.26
VC	29.20	2.01	1224.16	96.33	422.18	51.43
S2	21.58	1.70	1253.82	103.23	256.12	27.19
S4	23.40	2.27	905.60	58.48	302.00	32.80
S8	19.10	1.19	1035.46	112.73	248.40	29.71
S12	18.60	1.21	1013.89	37.93	223.20	25.93
S3-4	20.80	1.86	1316.00	122.88	332.90	34.28
S3-6	18.75	2.08	998.00	133.45	226.20	39.64
S3-10	19.60	1.46	1156.90	101.41	300.77	36.49
S3-14	18.13	1.57	980.10	86.38	221.70	25.47
S5-6	17.10	1.02	928.63	77.81	229.90	52.61
S5-8	18.16	2.30	849.50	73.39	183.56	27.39
S5-12	20.51	2.29	829.66	64.95	186.61	21.50

TABLE 3

Group differences in learning efficiency and the ratio of each difference to its sigma, showing the informative value of electric shocks for errors

GROUPS COMPARED	TRIALS		TIME		ERRORS	
	Difference	Ratio	Difference	Ratio	Difference	Ratio
N-S	26.90	5.60	433.14	3.17	232.64	4.43
N-VC	16.01	3.38	239.23	1.57	27.01	.38
VC-S	10.89	3.65	194.01	1.62	206.63	3.71
Sa-S	2.29	.84	35.14	.26	37.75	.92

the informative value in learning of such a cue which characterizes blind alley, as distinct from true pathway, segments. The learning scores are shown in table 2. The mean learning scores for group VC are: 29.20 trials, 1224.16 seconds, and 422.18 errors as compared with 45.21 trials, 1463.39 seconds, and 449.19 errors

for group N. The maze was thus mastered under the conditions of receiving a verbal cue at the end of each blind alley, as compared with ordinary conditions of learning, in 35.4 per cent fewer trials, 13.3 per cent less time, and with 6 per cent fewer errors. The difference scores, along with the ratio of each difference to its sigma, are shown in table 3. The chances in 100 that there is a true difference between the groups are, 99.9 in terms of trials, 93 in terms of time, and only 64 in terms of errors. Thus, informing the subject verbally that the end of a blind alley has been reached, has a pronounced effect upon trials, a fairly significant effect upon time, and a very slight but probably insignificant effect upon errors.

If the beneficial effect of electric shocks upon learning results primarily from their informative value in aiding the subject to distinguish blind alley from true pathway segments then, presumably, the effect should be roughly comparable to that which occurs when some pronounced non-punishment cue is given. Electric shocks, as shown above, result in a decrease of 59.5 per cent in trials, 29.6 per cent in time, and 51.7 per cent in errors, compared with N. The corresponding decrease which results from the use of a verbal cue is: 35.4 per cent in trials, 13.3 per cent in time, and 6 per cent in errors. The decrease in the S condition, over group N, is markedly greater according to all measures, trials, time, and errors, than that resulting from giving the subject the same information but in a manner not involving electric shocks. Especially is this true in terms of errors where the VC group shows a decrease of only 6 per cent while the effect of electric shocks upon learning was 51.7 per cent.

A comparison of the results of the VC group directly with those of group S, shows that the latter took 37.2 per cent fewer trials, required 16.2 per cent less time, and made 48.7 per cent fewer errors than the former. This increase in the efficiency of learning under the S condition is greater than that which the VC condition produced over group N (35.4 per cent, 13.3 per cent, and 6 per cent for trials, time, and errors respectively). The superiority of the S over the VC condition has a rather high degree of significance statistically, especially in terms of trials and errors.

Evidently, the beneficial effect of electric shocks in terms of trials and time is partly a function of the informative aspect involved in thus distinguishing errors from correct acts, while in terms of error scores the effect is almost entirely a function of the aspect involved other than the informative one, namely, punishment.

A second aspect of the problem concerning the informative value of electric shocks was investigated by varying the instructions which were given to the subjects prior to learning. The individuals in group S were informed in the instructions that a "slight shock" would be experienced when the stylus came in contact with the end of a blind alley. The instructions to group Sa contained no reference to the fact that shocks were to be used; otherwise the conditions of learning were the same for the two groups. The question here, then, concerns the value of the knowledge, prior to learning, that shocks are to be given at certain places in the maze. The learning scores for group S are: 18.31 trials, 1030.15 seconds, and 216.55 errors, compared with 20.60 trials, 1065.29 seconds, and 254.30 errors for group Sa (table 2). The efficiency of learning the maze was greater according to trials, time, and errors, under the S condition than under the Sa condition. The differences between the groups are in every case smaller than the corresponding sigmas, indicating low reliability statistically (table 3). The consistency of the results suggests, however, a slight superiority in the efficiency of learning when the subjects are informed that an electric shock is to be administered at the end of each blind alley than when no such information is given to them in the instructions prior to learning.

PROBLEM 2. WHAT IS THE EFFECT UPON LEARNING OF VARYING
THE NUMBER OF TRIALS DURING WHICH ELECTRIC
SHOCKS ARE ADMINISTERED?

The effect of varying numbers of trials with shocks was studied at three different positions in the learning process: (a) during the initial trials; (b) after 2 trials of learning under normal conditions; and (c) after 4 trials on the maze under normal conditions.

(a) Electric shocks during the initial trials

The number of initial trials during which shocks were administered was 2, 4, 8, and 12 for groups S2, S4, S8, and S12 respectively. The subjects in each of these groups were informed in the instructions that during the "first few trials" they would receive a slight shock when the stylus came in contact with the end of a blind alley. At the completion of the last trials during which shocks were given, the experimenter informed them that the trials thereafter which they required to reach the criterion of mastery would be under normal conditions. Group S received shocks

TABLE 4

Differences between groups, which received varying numbers of initial trials with shocks, in learning efficiency and the ratio of each difference to its sigma

GROUPS COMPARED	TRIALS		TIME		ERRORS	
	Difference	Ratio	Difference	Ratio	Difference	Ratio
N-S2	23.63	5.13	209.57	1.34	193.07	3.49
N-S4	21.81	4.49	557.79	4.29	147.19	2.53
N-S8	26.11	5.93	427.93	2.63	200.79	3.56
N-S12	26.61	5.97	449.50	2.83	225.99	4.13
N-S	26.90	5.60	433.14	3.17	232.64	4.43
S2-S4	-1.82	.64	348.22	2.93	-45.88	1.07
S2-S8	2.48	1.15	218.36	1.42	7.72	.19
S2-S12	2.98	1.43	239.93	2.18	32.92	.87
S4-S8	4.30	1.67	129.86	1.02	53.60	1.21
S4-S12	4.80	1.86	-108.29	1.55	78.80	1.88
S8-S12	.50	.29	21.57	.18	25.20	.63

throughout all trials during learning and hence represents the upper limiting condition in this respect. A comparison of the records of these groups with each other and with the records of group N, which learned the maze under normal conditions, will indicate the influence of the varying numbers of trials with shocks which were employed upon the efficiency of learning.

Results. The learning scores for each group are shown in table 2; the differences between the groups in learning efficiency and the ratio of each difference to its sigma are presented in table 4. The groups will be compared in terms of errors, trials, and time scores.

Errors. When the maze was mastered under normal conditions the mean error score was 449.19 as compared with a mean error score of 256.12, 302.0, 248.40, and 223.20 which occurred when shocks were administered during the first 2, 4, 8, and 12 trials respectively. The mean error score of the group which received electric shocks throughout all trials, group S, was 216.55. Thus, each of the groups with shocks exhibited decidedly greater efficiency in learning the maze than did group N, the control group. The difference between the shock groups and the control group has in each case a rather high degree of significance statistically. The ratios (table 4) indicate that the chances are over 99 in 100 that with repetition of the work each shock group would be superior to group N.

Further, comparative error scores suggest that a slight increase in efficiency of learning as the number of initial trials with electric shocks is increased from 2 through complete mastery, group S. For example, the decrease in the number of errors when shocks were used for 2, 4, 8, 12 trials, and during the entire learning process, as compared with the control group, was 42.9, 32.7, 44.7, 50.3, and 51.7 per cent respectively. The differences are very small, however, and are not entirely consistent as group S4 was less efficient than group S2. A direct comparison of group S2 with S8 and with S12 indicates that the chances in 100 of an increase in learning efficiency beyond that produced by 2 trials with shocks are 58 and 81 for 8 and 12 trials with shocks respectively. The ratio of the difference between the S2 and the S condition to its sigma is 1.22, which means that the chances are 88 in 100 that electric shocks throughout learning would be found to be more efficient than shocks during the first two trials only.

Thus, in terms of errors in learning, administering electric shocks during the first two trials only in the mastery of the maze was highly beneficial in learning, and a further increase in the number of such trials, e.g., 4, 8, 12, and all during learning, resulted in a further increase in efficiency which was slight and of doubtful significance statistically.

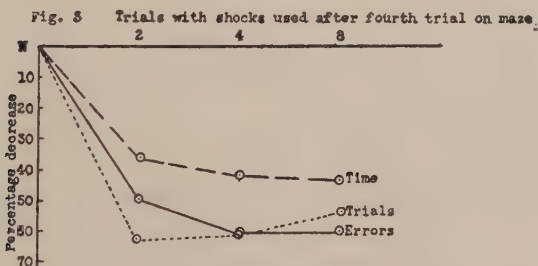
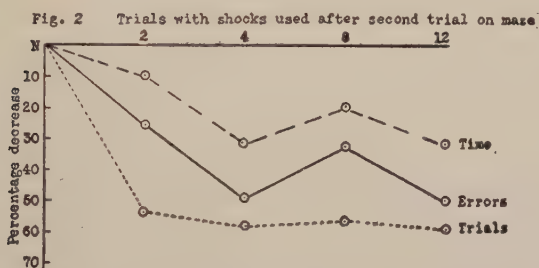
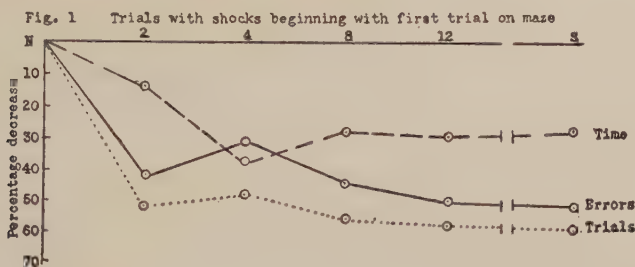
Trials. The effect of electric shocks is greater when measured

in terms of trials to learn than when error scores are used, although the relationship between the effect and the number of trials during which the shocks are used initially is somewhat the same as was found above in the case of errors. The maze was mastered in 45.21 trials under normal conditions, while only 21.58, 23.4, 19.10, and 18.6 trials were required when shocks were administered for 2, 4, 8, and 12 trials respectively. The mean number of trials taken in learning when shocks were used during the entire process of mastery was 18.31, group S. There is a fairly consistent increase in efficiency as the number of trials with shocks is increased from 2 through 4, 8, 12, and finally throughout learning. The percentage decrease in trials to learn, compared with N, was 52.2 for 2 trials with shocks, 48.2 for 4 trials, 57.7 for 8, 58.8 in the case of 12 trials with shocks, and 59.5 for the S condition. The differences are small and do not have a high degree of significance statistically, although they are fairly consistent. Compared directly with the S2 condition, the chances range from 87 to 93 in 100 that there is a true increase in efficiency of learning over that exhibited by the S2 group when shocks are used for either 8 or 12 trials or when continued throughout learning.

It is clear that the influence of electric shocks, in terms of trials, is very beneficial whether the shocks are limited to the first 2, 4, 8, 12 trials, or whether they are used throughout learning. A marked increase in the number of trials during which shocks are administered beyond the first 2 trials, e.g., 8, 12, or to complete mastery, results in only a slight increase in efficiency over that manifested when their use is limited to the first two trials. The small increase is of doubtful significance statistically.

Time. When efficiency of learning the maze is measured in terms of the total amount of time taken to reach the criterion of mastery, the effect of electric shocks is less than when either trials or error scores are used. But the effect is beneficial whether the shocks are administered for only a few trials or used throughout learning. Under ordinary conditions of maze-learning the amount of time taken was 1463.39 seconds, while group S2, S4, S8, and S12, took 1253.82, 905.6, 1035.46, and 1013.89 seconds

respectively. The amount of time taken by group S was 1030.15 seconds. Compared with N, the percentage decrease for S2, S4, S8, S12, and S, was 14.3, 38.1, 29.2, 30.7, and 29.6 respectively.



FIGS. 1, 2 and 3. The relationship between the number of trials with shocks and the percentage decrease in trials, errors, and time, compared with group N as a standard, when the shocks are used from the start (fig. 1), after two normal trials (fig. 2), and after 4 normal trials (fig. 3). Point S in figure 1 represents the condition of shocks for errors throughout all trials.

The least decrease in the time score in learning occurred when shocks were limited to the two initial trials. The chances are 90 in 100 that there is a true difference between these two groups,

S2 and N. The use of shocks for 4 trials increased efficiency 27.7 per cent over that which was shown under the S2 condition—an increase which is greater than that produced by 2 trials with shocks over group N. The ratio of the difference between group S4 and S2 to its sigma is 2.93, indicating a rather high degree of reliability. Further increases in the number of trials with shocks beyond 4 did not result in any additional increase in learning efficiency, in fact neither group S8, S12, nor S, reached the low time score of group S4 although the differences are relatively small.

The relationship between the number of initial trials with electric shocks during learning and the percentage decrease, compared with N, in terms of errors, time, and trials, is shown graphically in figure 1. It is obvious from an inspection of the curves that (1) varying amounts of initial trials with shocks increased the efficiency of learning the greatest amount in terms of trials, next in terms of error scores, and the least amount relatively in terms of time scores (this differential effect will be examined in a separate section later), (2) administering shocks during the first 2 trials only results in a decided increase in efficiency manifested in learning, and (3) as the number of initial trials with shocks is increased from 2 to 4, 8, 12, or throughout learning, there is only a slight further increase in learning efficiency, i.e., an increase beyond that resulting from only 2 trials with shocks.

(b) *The influence of varying numbers of trials with shocks when introduced after two trials of learning under normal conditions*

The subjects in groups S3-4, S3-6, S3-10, and S3-14, beginning with the third trial on the maze, received 2, 4, 8, and 12 trials with shocks respectively. The first two trials on the problem were, of course, under ordinary maze-learning conditions, as were all trials taken by the subjects after the specified series of trials with shocks. At the beginning of the series of trials with shocks, the subjects were informed that shocks would be used during the next "few trials." At the end of the series they were informed that the trials thereafter would be under normal conditions. A

comparison of these groups with each other and with group N will indicate the effect of electric shocks upon learning when the trials with shocks are after two normal trials.

Results. The learning scores of the above groups are presented in table 2. The differences between the groups and the ratio of each difference to its sigma are shown in table 5. The groups are compared in terms of the measures of efficiency used.

Errors. The mean error score of group N was 449.19. When 2, 4, 8, and 12 trials with shocks were used after 2 trials under normal conditions, the averages in terms of errors were 332.9,

TABLE 5

Group differences in learning efficiency when shocks are introduced after 2 trials under normal conditions

GROUPS COMPARED	TRIALS		TIME		ERRORS	
	Difference	Ratio	Difference	Ratio	Difference	Ratio
N-S3-4	24.41	5.22	147.39	.87	116.29	1.97
N-S3-6	26.56	5.57	465.39	2.62	222.99	3.58
N-S3-10	25.61	5.65	306.49	1.98	148.42	2.46
N-S3-14	27.08	5.93	483.29	3.32	227.49	4.18
S3-4-S3-6	2.05	.73	318.00	1.75	106.70	2.03
S3-4-S3-10	1.20	.50	159.10	.99	32.13	.64
S3-4-S3-14	2.67	1.09	335.90	2.23	111.20	2.60
S3-6-S3-10	-.85	.33	-15.80	.94	-74.57	1.38
S3-6-S3-14	.62	.23	17.9	.11	4.5	.09
S3-10-S3-14	1.47	.68	176.8	1.32	79.07	1.78

226.2, 300.7, and 221.7 respectively. These figures represent a decrease of 25.8, 49.6, 33.0, and 50.6 per cent in the number of errors made in earning for 2, 4, 8, and 12 trials with shocks respectively. The ratios of these differences to their respective sigmas (table 5) indicate that the chances are 98 or greater in 100 that efficiency of learning under each of the shock conditions is superior to that manifested under normal conditions.

The results suggest that as the number of trials with shocks is increased, the effect upon learning is greater, although the data are not entirely consistent in this respect as 8 trials were less effective than 4. Twelve trials with shocks were more effective

than 4, but the difference between them is slight and probably not significant (table 5). Apparently, efficiency of learning increases rapidly as the number of trials with shocks is increased from 2 to 4, while further increases in the number of such trials are of doubtful value from the standpoint of resulting in additional improvement in learning.

Trials. The introduction of electric shocks, following two trials of normal learning, results in a marked increase in efficiency in terms of trials whether the shocks are used for 2, 4, 8, or 12 trials. The number of trials taken by group N to learn the maze was 45.21, while the corresponding score was 20.8 for group S3-4, 18.75 for S3-6, 19.60 for S3-10, and 18.13 for S3-14. The difference between each of these groups and group N, compared with the latter as a standard, represents a percentage decrease of 53.9, 58.7, 56.6, and 59.8 in the number of trials to learn for 2, 4, 8, and 12 trials with shocks respectively. The superiority of each of the shock groups over group N is great, and the ratio of each difference to its sigma is over 5 in all cases (table 5).

Comparative data concerning the relative efficiency of the various shock groups yield differences which are small and of low reliability statistically. The efficiency of learning is greater when 4, 8, or 12 trials with shocks are used than when only 2 are employed, but in only one instance is the difference as large as its sigma and in this one exception the ratio is only 1.09.

Time. Administering shocks for varying numbers of trials, after 2 under normal conditions, is also beneficial in terms of the total amount of time taken, although the effect is less than that which occurs in terms of trials and errors. The normal group made a time score of 1463.39 seconds as compared with a score of 1316.0 seconds for group S3-4, 998.0 seconds for S3-6, 1156.90 seconds for S3-10, and 980.1 seconds for S3-14. The differences involved, compared with group N, represent a percentage decrease of 10.0, 31.8, 20.9, and 33.0 for 2, 4, 8, and 12 trials with shocks respectively. The ratios, shown in table 5, indicate that the chances are approximately 98 or greater in 100 that 4, 8, or 12 trials with shocks would be found to be beneficial in learning, while they are only 81 in 100 that 2 trials with shocks would result in a level of efficiency superior to that of group N.

As indicated above, the effect of 2 trials with electric shocks was a decrease of 10 per cent in the time score, while the effect consequent upon 4 trials with shocks was 31.8 per cent. A comparison of group S3-6 directly with the S3-4 condition indicates that the chances are 96 in 100 that there is a true increase in the efficiency of learning as the result of an increase in the number of trials with shocks from 2 to 4. Further increases beyond 4 did not result in significantly greater learning efficiency than that exhibited by group S3-6. In other words, efficiency of learning increased markedly as the number of trials with shocks was increased from 2 to 4, while further increases in the number of shock trials beyond 4 are of doubtful significance.

The relationship between the number of trials with shocks, following two trials of learning under normal conditions, and the percentage decrease which occurred over group N, is shown graphically in figure 2. An inspection of the curves shows that (1) electric shocks increase the efficiency of learning markedly by all methods of measurement employed, and these methods rank in decreasing order of efficiency as follows: trials, errors, and time, (2) approximately the maximum beneficial effect from shocks in terms of trials as a measure of learning was reached when only 2 such trials were used, and in terms of errors and time scores when 4 trials were used.

(c) *The influence of varying numbers of trials with shocks when introduced after 4 trials of learning under normal conditions*

A comparison of the learning records of groups S5-6, S5-8, and S5-12 with each other and with the records of group N is involved here since these three shock groups received, in the order named, 2, 4, and 8 trials with shocks after having completed the fourth normal trial. The learning data are presented in table 2; the differences between the groups and the ratio of each difference to its sigma are shown in table 6.

Errors. The results of administering shocks of 2, 4, and 8 trials at this position in learning was a decrease of 48.8, 59.2, and 58.9 per cent respectively in the number of errors made in

learning the maze as compared with the error record of group N. For example, 449.19 is the average error score of group N, while the corresponding figure for group S5-6 is 229.9, for group S5-8 is 183.56, and for group S5-12 is 186.61 (table 2). The ratio of the difference between each shock group and group N to the sigma of the difference is 3 or greater (table 6) in every case. The efficiency of learning under any of the three shock conditions is significantly superior to that shown under normal conditions.

A comparison of the shock groups, S5-6, S5-8, and S5-12, with each other indicates that the efficiency of learning is greater when either 4 or 8 trials with shocks are used than when only 2

TABLE 6

Group differences in learning efficiency when shocks are introduced after 4 trials under normal conditions

GROUPS COMPARED	TRIALS		TIME		ERRORS	
	Difference	Ratio	Difference	Ratio	Difference	Ratio
N-S5-6	28.11	6.38	534.76	3.81	219.29	3.07
N-S5-8	27.05	5.81	613.89	4.44	265.63	4.80
N-S5-12	24.70	5.08	633.73	4.73	262.58	4.98
S5-6-S5-8	-1.06	.42	79.13	.73	46.34	.78
S5-6-S5-12	-3.41	1.36	98.97	.97	43.29	.76
S5-8-S5-12	-2.35	.72	19.84	.02	-3.05	.08

are used, although the additional increment in efficiency is in each case smaller than its sigma (table 6).

Trials. The number of trials required to master the maze is markedly reduced as the result of electric shocks under conditions S5-6, S5-8, and S5-12, compared with the number required when no shocks are given during learning. The mean trial score for group N is 45.21, while the trial score for group S5-6 is 17.1, for group S5-8 is 18.16, and for S5-12 is 20.51. These figures represent a decrease, compared with N, of 62.1, 59.8, and 54.6 per cent respectively for 2, 4, and 8 trials with shocks.

The beneficial influence of electric shocks upon learning was greatest when the shocks were limited to 2 trials. The difference,

however, between the use of 4 or 8 trials with shocks as compared with 2, does not have a high degree of significance statistically.

Time. In learning the maze groups S5-6, S5-8, and S5-12 exhibited significantly lower time values than group N, e.g., mean scores of 928.63, 849.5, and 829.66 seconds respectively, as compared with 1463.39 seconds for N. Further, the efficiency of learning increased slightly as the number of trials with shocks was increased from 2 to 8. The percentage decrease, over N, in the amount of time taken in learning was 36.5 for 2 trials with shocks, 41.9 for 4, and 43.3 when shocks were used for 8 trials. The additional increase over the level of efficiency shown when shocks were limited to 2 trials is slight and of doubtful significance.

The relationship between the number of trials with electric shocks, following the 4th normal trial on the maze, and the percentage decrease with respect to group N, is represented graphically in figure 3. The curve show that (1) the effect of electric shocks varies somewhat with the method of measurement, (2) the increase in efficiency resulting from the shocks is, relatively, greatest in terms of trials, with errors and time scores following in the order named, and (3) the maximum effect of shocks was reached approximately when this variable was used either for 2 or for 4 trials, depending upon the criterion of learning.

(d) *Relative efficiency during the process of learning*

a. *The differential effect of electric shocks upon trials, errors, and time scores.* It has been noted in the problems discussed above that the effect of shocks upon learning varied with the method of measurement. Shocks were beneficial to learning in all cases, but there was a greater percentage decrease in trials than in errors or time, and a greater decrease in errors than in time. The relatively greater decrease in trials suggests that more errors were made and more time taken per trial in the groups which received shocks than in the group which learned the maze under normal conditions. The data were analysed to determine if such a result occurred. The average amount of time taken and the mean error record at different stages of learning in terms of trials were determined for a considerable part of the learning process. These data

are represented graphically in terms of errors in figure 4, and in terms of time scores in figure 5. A comparison of the error curve of group S with that of group N shows that under the shock condition there were fewer errors at each stage of learning than occurred under normal learning, and the decrease was roughly proportional at the different stages of mastery. Apparently,

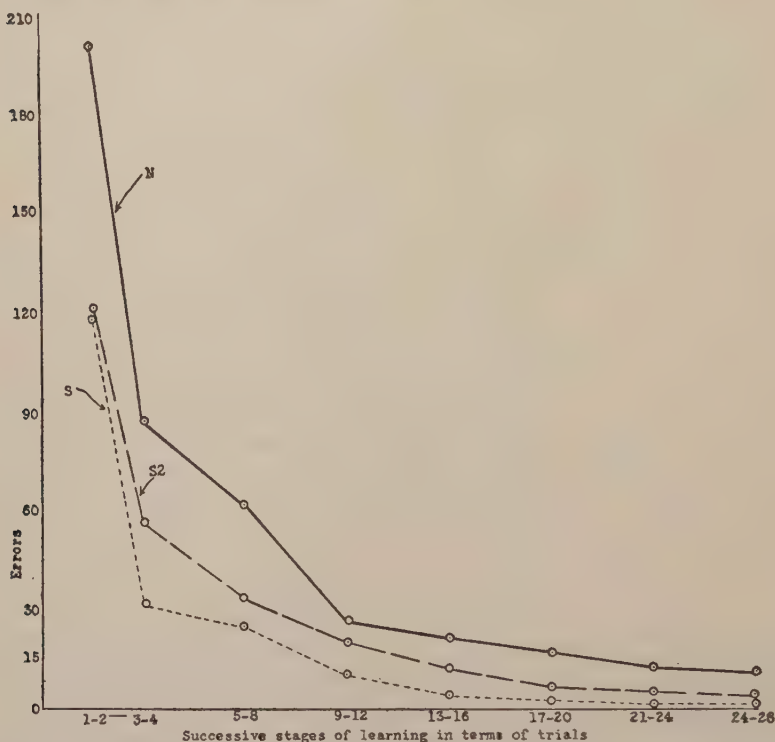


FIG. 4. AVERAGE ERROR SCORES AT SUCCESSIVE STAGES OF LEARNING IN TERMS OF TRIALS

since shocks decreased errors per trial, the small difference between the relative decrease in total trials and total errors—59.5 per cent in the former and 51.7 per cent in the latter—is a function of the fact that the last errors in group N to be eliminated were distributed over a relatively large number of trials. The picture varies somewhat when the time curves are considered. Under the shock condition, the amount of time taken per trial at

first increased and then decreased as learning progressed. Group S, for example, took more time during the first 2 trials of learning than did group N, although fewer errors were made in these trials. Evidently the difference between the amount of decrease in total errors and that in terms of total time, which resulted from the use of shocks, is largely a function of the differential effect of electric shocks upon these measures in the early stages of learning.

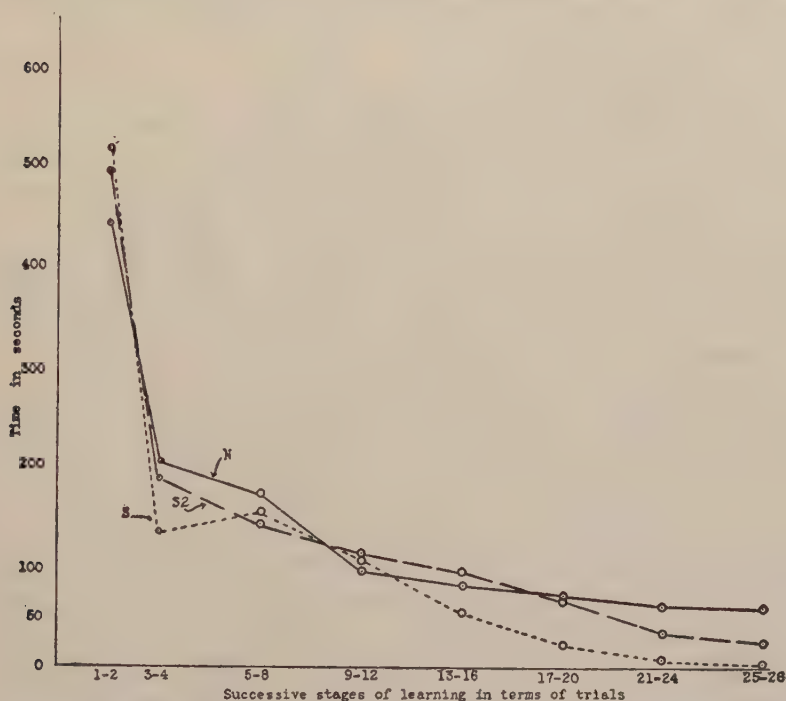


FIG. 5. AVERAGE TIME SCORES AT SUCCESSIVE STAGES OF LEARNING IN TERMS OF TRIALS

Somewhat the same result is found when shocks are used for a limited number of trials during the initial position in learning, and following the second normal trial. Curve S2 in figure 5 is given as an example. There was an increase in the amount of time taken in the early trials, as a result of electric shocks; trials 1 to 2 when shocks were used in the initial trials, and 3 to 4 when they were introduced after the second normal trial. That the differ-

ential effect of shocks upon total time and errors has its locus in the early trials under the shock condition, is further indicated by the fact that when shocks were introduced following the fourth normal trial there was a decrease in time per trial, as well as errors, and the difference between the two total scores was less in this case. Apparently the relationship between the changes in time and error scores during the first few trials with shocks varies to some extent with the stage of learning at which the shocks are introduced.

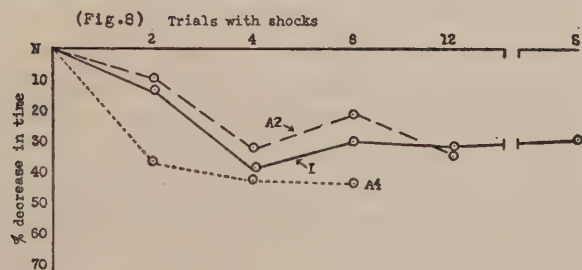
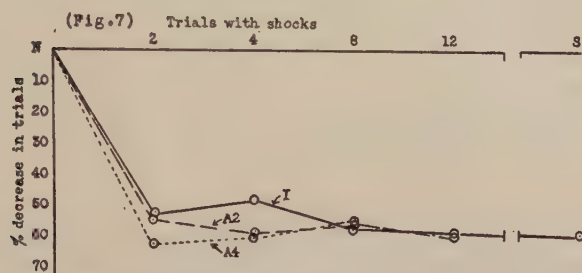
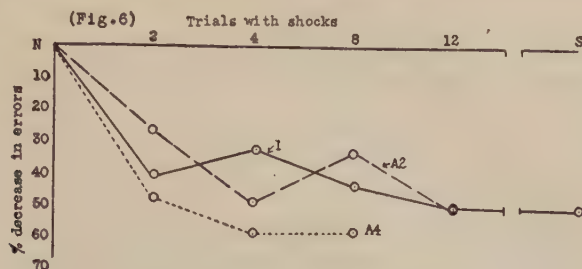
One additional point with respect to time and error scores per trial when shocks are used, may be noted. A decrease in errors combined with an increase in time on the same trials does not indicate clearly that the subjects were responding more slowly and cautiously to the aspects of the problem than occurred under normal conditions, as error scores represent the number of times the subject moved the stylus away from or in the backward direction of the true pathway and not excess distance traversed with the stylus.

b. *Efficiency during the post-shock trials.* These data also show that when shocks were used for a limited number of trials, the efficiency of learning during the post-shocks trials was greater than was the case at the corresponding stages of learning in group N. The error score per trial during the normal trials subsequent to those with shocks was considerably lower than in group N, although not so low as when shocks were used throughout all trials, group S. A glance at curves S2, S, and N in figure 4 shows that group S2, which had more normal trials in learning subsequent to those with shocks than the other groups, maintained an error record during its post-shock trials at somewhat the same intermediate position with respect to curves S and N. There was a decrease also in the time scores during the post-shock trials, but these results were more irregular than the error records.

PROBLEM 3. WHAT IS THE RELATIONSHIP BETWEEN THE INFLUENCE OF THE VARIOUS TRIALS WITH SHOCKS AND THE STAGE OF THE LEARNING PROCESS AT WHICH THE TRIALS ARE USED?

In the preceding sections data have been presented which show that electric shocks have a beneficial effect upon learning when

administered at three different positions in learning. The problem here is concerned with the variation in the effect with position, and resolves itself into two questions: (a) is the influence of



FIGS. 6, 7 and 8. The beneficial influence upon learning of varying numbers of trials with shocks, compared with group N as a base, at three different stages of learning is shown in terms of errors in figure 6, trials in figure 7, and time scores in figure 8. Point S represents the condition of shocks for errors throughout all trials.

I—shocks during initial trials.

A2—shocks introduced after second trial on maze.

A4—shocks introduced after fourth trial on maze.

a specified number of trials with shocks a function of the position in learning at which such trials are used, and (b) is the relative effect of the various trials with shocks used, a function of the stage of learning?

No new data are involved in considering these questions. The learning scores of the groups already described are brought together in a different way for the comparisons here. The effect of the different series of trials with shocks, which occurred at each of the three stages of learning, is shown graphically in terms of errors in figure 6, in terms of trials in figure 7, and in terms of time scores in figure 8. For example, three error curves are shown in figure 6, and each curve represents the effect of various trials with shocks when used at one of the three stages of learning studied. These data are summarized in table 7. In table 8 are presented the differences between the various groups, and the ratio of each difference to its sigma, showing the significance of the changes in efficiency when a specified number of trials with shocks is used at different stages of learning. In other words, the ratios in table 8 indicate the significance statistically of the difference between vertical points in figures 6, 7, and 8.

(a) *The influence of a specified number of trials with shocks at different positions in learning*

Errors. When efficiency of learning is measured in terms of error elimination, the data indicate that the later a given number of trials with shocks is introduced in the process of learning, within the limits studied, the greater is the efficiency of learning. The data are rather consistent in indicating this general trend; there are two exceptions in eleven comparisons. These exceptional cases appear in the comparison of the influence of electric shocks when introduced after the second trial with their influence when given initially. When introduced after the fourth trial on the maze, 2, 4, and 8 trials with shocks were more effective than the same number of such trials used at either of the earlier stages of learning, and most of the differences are fairly significant statistically. The ratios (table 8) show, however, that the chances are only 66 in 100 that 2 trials with shocks after the fourth trial are more effective in learning than 2 trials with shocks given initially, although the chances are 95 in 100 that 2 trials with shocks are more effective when they occur during trials 5 and 6 than when they occur during trials 3 and 4. Further, the chances

are 99.7 in 100 that 4 trials with shocks on trials 5 to 8 are more effective in learning than when used during the first 4 trials, and

TABLE 7

Percentage decrease in learning scores from varying numbers of trials with shocks when given at three different stages of the learning process

STAGES OF THE LEARNING PROCESS	NUMBER OF TRIALS WITH SHOCKS														
	2			4			8			12			Throughout learning		
	Trials	Time	Errors	Trials	Time	Errors	Trials	Time	Errors	Trials	Time	Errors	Trials	Time	Errors
Initial	52.2	14.2	42.9	48.2	38.1	32.7	57.7	29.2	44.7	58.8	30.7	50.3	51.7	29.6	59.5
After second trial..	53.9	10.0	25.8	58.7	31.8	49.6	56.6	20.9	33.0	59.8	33.0	50.6			
After fourth trial	62.1	36.5	48.8	59.8	41.9	59.2	54.6	43.3	58.9						

TABLE 8

Group differences in learning efficiency between the groups with shocks, and the ratio of each difference to its sigma, when the specified trials with shocks occur at different stages of learning

	TRIALS		TIME		ERRORS	
	Difference	Ratio	Difference	Ratio	Difference	Ratio
2 trials with shocks:						
S2-S3-4	.78	.31	-62.18	.38	-76.78	1.70
S2-S5-6	4.48	2.35	325.19	2.51	26.22	.44
S3-4-S5-6	3.7	1.67	387.37	2.66	103.00	1.64
4 trials with shocks:						
S4-S3-6	4.65	1.25	-92.4	.63	75.80	1.47
S4-S5-8	5.24	1.63	56.1	.59	118.44	2.77
S3-6-S5-8	.59	.19	148.5	.97	42.64	.88
8 trials with shocks:						
S8-S3-10	-.50	.26	-121.44	.80	-52.37	1.11
S8-S5-12	-1.41	.54	205.80	1.58	61.79	1.66
S3-10-S5-12	-.91	.33	327.24	2.71	114.16	2.69
12 trials with shocks:						
S12-S3-14	.47	.23	33.79	.34	1.50	.04

95 in 100 that 8 shocks trials, after 4 without, result in more efficient learning than that which occurs when shocks are used during the first 8 trials.

Also, when as many as 4 trials with shocks were used at the third position studied, fewer errors were made than when 2, 4, 8, or 12 such trials were used at either of the earlier stages of learning. For instance, efficiency of learning under the S5-8 condition is 17.3 per cent greater than that exhibited by group S12, 17.2 per cent greater than that manifested by group S3-14, and even 10 per cent superior to the efficiency shown when shocks were used through the entire learning process. The efficiency of learning under the S5-8 condition would be found to be superior to that shown under either the S12, the S3-14, or the S condition, approximately 84 times in 100.

These data indicate that (1) the influence of a specified number of trials with shocks is partly a function of the stage of the learning process at which such trials are used, (2) in general, the later the series of trials with shocks is introduced in learning, within the limits studied, the greater the increase in learning efficiency, and (3) that a limited number of trials with shocks, e.g., 4, introduced after four trials under normal conditions, results in fewer errors in learning than the use of a considerably larger number of trials with shocks at an earlier position.

Trials. According to the data obtained when 2 trials with shocks were introduced at three different stages of learning, the later the trials with shocks are introduced the greater the decrease in the total number of trials to learn (figure 7). The three groups which received shocks for 2 trials rank, in decreasing order of efficiency, as follows: S5-6, S3-4, and S2. Although the superiority of S3-4 over S2 is less than one full trial, and of low reliability statistically, group S5-6 took 17.7 per cent fewer trials than did S3-4, and 20.7 per cent fewer than the number taken by group S2, and these differences are fairly significant statistically.

Somewhat the same relationship is found between the effect of shocks and the position in learning at which such trials are given, when 4 trials with shocks are used. Group S5-8 took 22.3 per cent fewer trials to learn the maze than did group S4, group S3-6

required 19.8 per cent fewer trials than did S4, and the differences are fairly significant (table 8). Although group S5-8 was superior to group S3-6, the difference is small.

When, however, as many as 8 or 12 trials with electric shocks are used, the increase in the efficiency of learning in terms of trials does not vary significantly with the stage of learning at which such trials are introduced. The mean number of trials taken to learn the problem, under the conditions of 8 trials with shocks, was 19.1 when the 8 trials in question were the initial ones, 19.6 when they were introduced after the 2nd trial, and 20.51 when introduced after the 4th trial on the problem. There is a suggestion here of a decrease in the effect of shocks as this variable is introduced later and later in learning, but the differences are small and of doubtful significance (table 8). The change in efficiency is even less when the effect of 12 trials with shocks at different stages of learning is considered; the maze was mastered in 18.6 trials by group S12, and in 18.13 trials by group S3-14.

Thus, comparative scores, in terms of trials as a measure of learning, indicate that (1) the effect of 2 or 4 trials with electric shocks varies with the degree of learning, (2) the later 2 or 4 trials with shocks occur during learning, the greater the effect, and (3) the beneficial influence of a relatively large number of trials with shocks, 8 or 12, does not vary significantly with the stage of learning at which they are used.

Time. An examination of the curves in figure 8 shows that the effect of either 2, 4, or 8 trials with shocks, is greater when the particular series of shock trials occurs at position 3 in learning than when given at either of the earlier stages studied. For instance, 2 trials with shocks are 25.9 per cent more effective when introduced after the completion of the fourth trial than when given initially, 4 trials with shocks during trials 5 to 8 are 6.19 per cent more effective than when the shocks occur during the first 4 trials, and 8 trials with shocks, after 4 without, resulted in the problem being learned in 19.8 per cent less time than the amount taken when shocks occurred during trials 1 to 8. When compared with the same number of trials with shocks at the second position in learning, the superiority of 2, 4, or 8 such trials at

the third stage is even greater than the corresponding figure mentioned above, since at the second position in learning each series of trials with shocks resulted in slightly poorer time scores than when used during the initial trials.

The efficiency of learning the maze under the condition of 12 trials with shocks, is approximately the same when the shocks occur during trials 1 to 12 as when they are given during trials 3 to 14.

Apparently then, the decrease in the amount of time taken to learn the problem resulting from 2, 4, or 8 trials with shocks (1) varies with the stage of learning at which these trials are used, (2) is greatest when they occur at the third position studied, and (3) is consistently greater, although the difference in each case is considerably smaller than its sigma, when they occur during the initial trials than when used at the completion of the second normal trial. The effect of 12 trials with shocks was not found to vary with position.

Although the effect of electric shocks at the different positions in learning varies somewhat with the method of measurement employed, the three measures are in agreement on the following points: (1) the influence upon learning of either 2 or 4 trials with shocks is greater when they are introduced at the third position studied than when used earlier in learning, (2) four trials with shocks at position three are more effective than 8 or 12 at an earlier stage in learning, and slightly more effective than shocks throughout all trials, and (3) the influence of an extended series of trials with shocks, 12, is not a function of position, within the limits studied.

Trials, time, and error scores are not in agreement in certain respects. For example, time scores stand alone in indicating that 2, 4, and 8 trials with shocks are less effective at the second position than the corresponding number of trials in the initial position. According to trials, the effect of shocks does not vary with position when as many as 8 such trials are used (all measures indicate such a result when 12 are used, as stated above). The stage of learning is relatively a more important variable when 2 trials with shocks are used, in terms of time scores than in errors or trials.

In regard to this last point, it will be recalled that electric shocks increased the time per trial during the first few trials of their use, except when introduced at position three in learning.

(b) *Is the relative effect of the various trials with shocks, a function of the stage of learning?*

The relative effect of varying numbers of trials with shocks was shown in Problem 2 above for each of three different positions in learning. A comparison of these results will indicate whether or not the relative effect varies with the position in learning at which the trials with shocks are introduced.

The data for these comparisons are shown graphically in figures 6, 7, and 8. At each of the three positions in learning at which shocks were used, the maximum effect was reached approximately from the use either of 2 or 4 trials with shocks and in no case did the use of a greater number of such trials result in a further significant or marked increase in efficiency. Whether this maximum effect was reached from the use of only 2 or from 4 trials with shocks depends upon the method of measuring learning; the figure is 2 in terms of trials, but more often 4 in terms of time and error scores. Although the relative effect of 2, 4, etc., trials with shocks does not vary significantly with the position in learning at which these trials are used, the magnitude of the increase in efficiency with respect to group N as a base, is a function of position. In almost all comparisons, the efficiency of learning was greater when the shock variable occurred at the third position in learning than when it was used at either of the earlier stages studied. Whether shocks are more effective at the first or the second position in learning is a function of both the number of trials during which they are administered and the criteria of efficiency, as described in the preceding section.

The particular combination of position and trials with shocks, which is the most effective in learning, is 2 trials with shocks at the third position according to trials as a measure, and 4 trials with shocks at the third position according to time and error scores.

SUMMARY AND DISCUSSION

Three problems concerning the effect of electric shocks for errors in learning a stylus maze were studied in this experiment. The subjects received an electric shock (27 volts A.C.) in the fingers grasping the stylus when the latter came in contact with the end of a blind alley. Undergraduate students were used as subjects and a different group was used for each condition of learning studied. The problems studied are as follows: (1) whether or not the effect of electric shocks is entirely a function of their informative value in learning; (2) the effect of varying numbers of trials (2, 4, 8, 12) with electric shocks at different positions in learning; (3) the relationship between the effect of the various trials with shocks and the stage of the learning process at which the trials were used. Three positions in learning are involved: the initial trials, the trials immediately following the second one under normal conditions, and those immediately subsequent to the fourth normal trial.

1. The efficiency of learning was greater under each of the 13 different conditions in which electric shocks were employed in the study than it was under normal conditions. In no instance (39 comparisons) were electric shocks for errors detrimental in learning.

2. The effect of electric shocks is partly a function of their informative value in distinguishing incorrect from correct acts.

The presence of a marked additional, but non-punishment, cue at the end of each cul-de-sac was helpful in terms of trials and time scores but not so effective as when the subjects were given electric shocks at these places in the maze. The verbal cue had only a very slight influence upon the number of errors made in learning, and hence the decidedly beneficial effect of electric shocks in this respect was almost entirely a function of the aspect involved other than the informative one, namely, punishment.

Another result in regard to the informative value of shocks for errors is that the shocks were slightly more effective in learning when the subjects were informed in the instructions prior to learning that shocks were to be used than when they were not given this information. The differences are small, but the con-

sistency of the results suggests a slight superiority under the conditions of prior knowledge. Several possible reasons for this slight increase in efficiency may be mentioned; any disturbing effects from the first few shocks may have been greater when the shocks were unexpected; greater motivation to learn from the moment the first trial was started than when they were not aware that shocks were to be used; and, an earlier grasp of the significance of the places in the maze which gave shocks than occurred when the subjects discovered this information for themselves only after having made a certain number of errors.

Further facts indicating that the effect of electric shocks is only partly a function of their informative value may be mentioned: efficiency of learning was greater during the post-shock trials than was the case at the same stages in learning when electric shocks had not been used at all; and, the effect upon learning was as great from the use of 4 trials with shocks as when 8 or 12 were used. If the effect of electric shocks were mainly a function of their informative value, one would expect the presence of the additional sensory cue to continue to have some informative value, and hence facilitate learning, as long as the subject experiences difficulty in distinguishing incorrect from correct segments, in other words, until the problem is learned.

3. The effect upon learning of a limited number of trials with electric shocks, e.g., 2 or 4, is: (a) a function of the stage of learning at which such trials are introduced; (b) greater when used at the third position studied than when administered earlier in learning; and (c) greater than that of a larger number of trials with shocks, 8 or 12, earlier in learning, and slightly greater than the use of electric shocks for errors during all trials.

4. The influence of as many as 12 trials with shocks does not vary with the stage of learning at which such trials are used, within the limits studied.

5. At each of the three stages of learning studied, the maximum effect of electric shocks was reached approximately from the use either of 2 or 4 trials with shocks, and in no instance did the use of a greater number, 8 or 12, result in a further significant or marked increase in efficiency.

6. The particular combination of position in learning and the number of trials with shocks, which was found to be the most effective in learning, was 2 trials with shocks at the third position according to trials as a measure, and 4 trials with shocks at the third position according to time and error scores.

In a study by Valentine on the maze learning of rats (20) it was found that the influence of electric shock punishment varied with the degree of learning present at the time punishment was introduced. Also, that punishment introduced relatively late in learning, and continued thereafter until mastery, was more effective than punishment introduced at a slightly earlier stage of learning. Although the present study differs from Valentine's in many ways, the results in human maze-learning are similar to those obtained with rats in two respects. A limited number of trials with shocks in the work reported here, varied with the degree of learning, and was more beneficial when introduced after the second of two degree of partial learning.

An explanation of the effect of electric shocks in learning cannot be given, but certain factors which bear on the problem may be mentioned. For instance, the greater effect of electric shocks at the third position in learning may be, to some extent, a function of both the informative and punishment aspects of shocks for errors. The method of giving the subject information about certain characteristics of the problem involved in the present study is quite different from that employed in an experiment by Ludgate, but it is indicative that the knowledge of the true pathway which resulted from manual guidance in her experiment was, according to some measures, of slightly greater aid in learning when introduced after a certain amount of partial learning than when given initially. In regard to the punishment aspect, it may be that any disturbing or distracting effects from electric shocks are greater when the subject is just beginning the task when certain general information about the problem has been acquired, such e.g., as the general direction of the goal from the starting point, etc. The possible relationship between difficulty and optimal intensity of electric shock noted in the Introduction, suggests that the intensity of the shock may be a factor influencing the effect of position. For instance, a weak intensity of shock

might be more effective when introduced initially in learning than after a certain degree of partial learning, while the reverse might be found for a more intense shock. There is of course an upper limit in regard to the beneficial effect of later positions, as the opportunity for a marked decrease in total scores would be less if punishment were introduced very late in learning.

If an increase in motivation to learn is regarded as the important factor in the explanation of the results, then apparently it is about as effective to produce this increase by the use of a limited number of punishment trials as by the use of a much greater number, and more effective in learning to bring about the increase by the use of a limited number of such punishment trials after the problem has been partly learned than by the use of the same, or greater, number of such trials at the beginning of the learning process.

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